Intercomparison of high-resolution climate models of tropical cyclones

Kevin Walsh, Sally Lavender, TCMIP Project Members

Thanks to Woodside Energy, Australian Research Council Network for Earth System Science, Debbie Abbs and Marcus Thatcher (CSIRO) and TCMIP members

Motivation

- TCMIP – the Tropical Cyclone climate Model Intercomparison Project
  - About 30 members
  - Initial goals:
    - Use common metrics to compare simulations of TCs in coarse-resolution CMIP3 model output
    - Solicit contributions of high-resolution climate model output for intercomparison, using standard metrics
  - Ultimate goal:
    - Improvement of high-resolution TC climate models (global and regional) through systematic intercomparison
  - http://www.earthsci.unimelb.edu.au/~kwalsh/tcmip_index.html

Metrics – Phase 1 (climatological fields)

- Vertical wind shear, SST, mslp, precip., convective precip., surface fluxes
- Emanuel MPI, SGP
- mid-tropospheric r.h., 850 hPa rel. vort, EKE, 100 hPa temp

Emanuel and Nolan GP

$$I = \left|10^5 \eta\right|^{\frac{3}{2}} \left(\frac{H}{50}\right)^3 \left(\frac{V_{pot}}{70}\right)^3 (1 + 0.1 V_{shear})^{-2}$$

There is also an revised version of this GP

Previous related intercomparison work

- Camargo et al. (2007) Tellus
  - Five models, forced with observed SSTs: compared Emanuel and Nolan GP to observed values and patterns of TC formation
  - Higher GP than reanalysis-based GP in most models
- Yokoi et al. (2009) Clim Dyn
  - PCMDI CMIP-3 models (coupled models)
  - Simulated GP mostly less than reanalysis-based GP in these models
- Vidale et al. (2009)
  - Recent high-res model (this conference)

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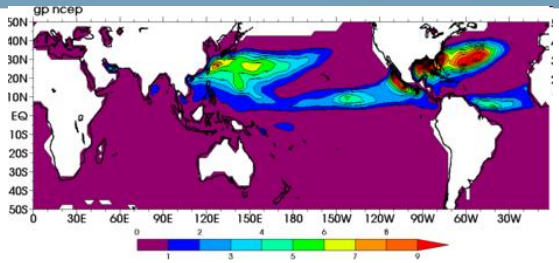
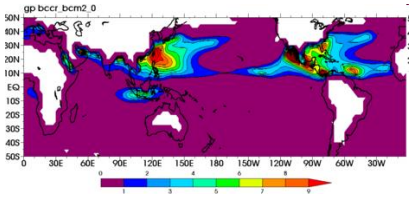
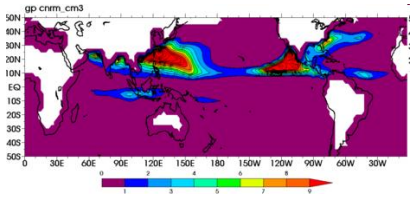
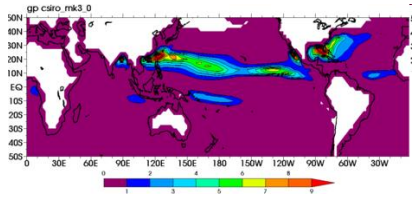
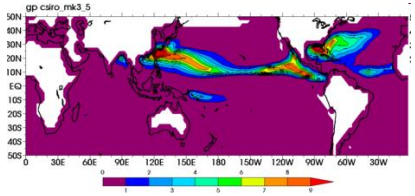
GP – July-Sept. climatology

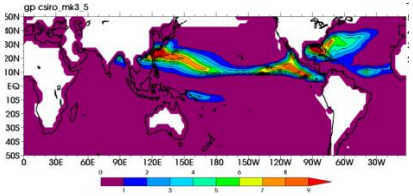


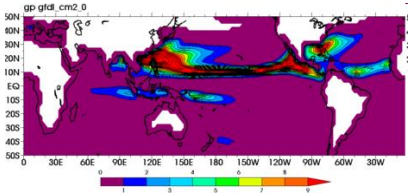


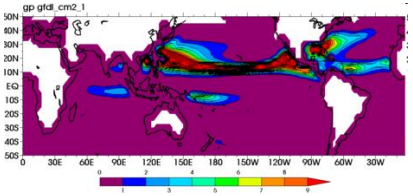


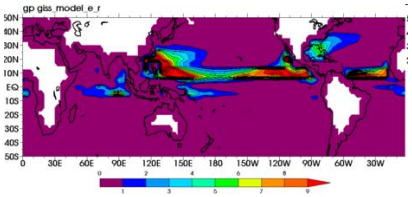


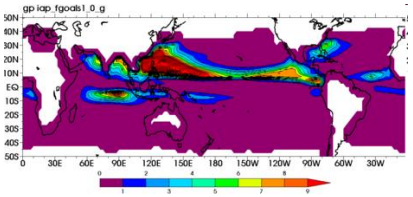


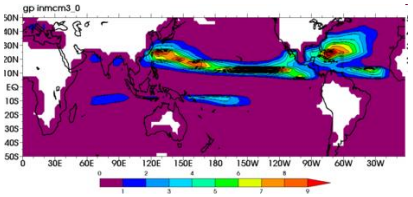


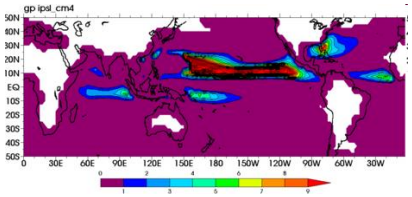


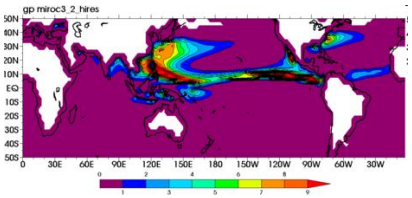


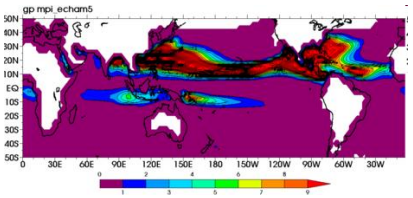


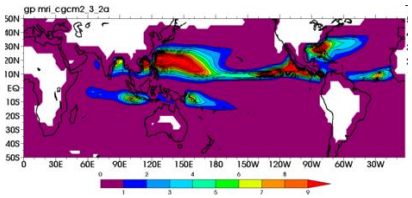


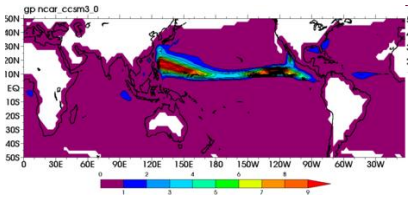


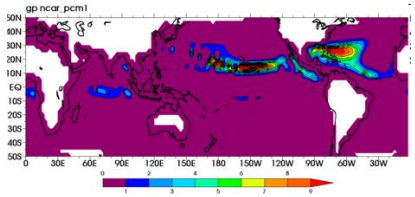


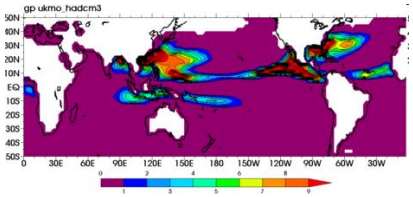


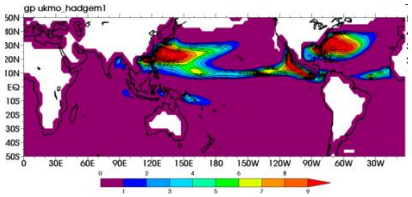




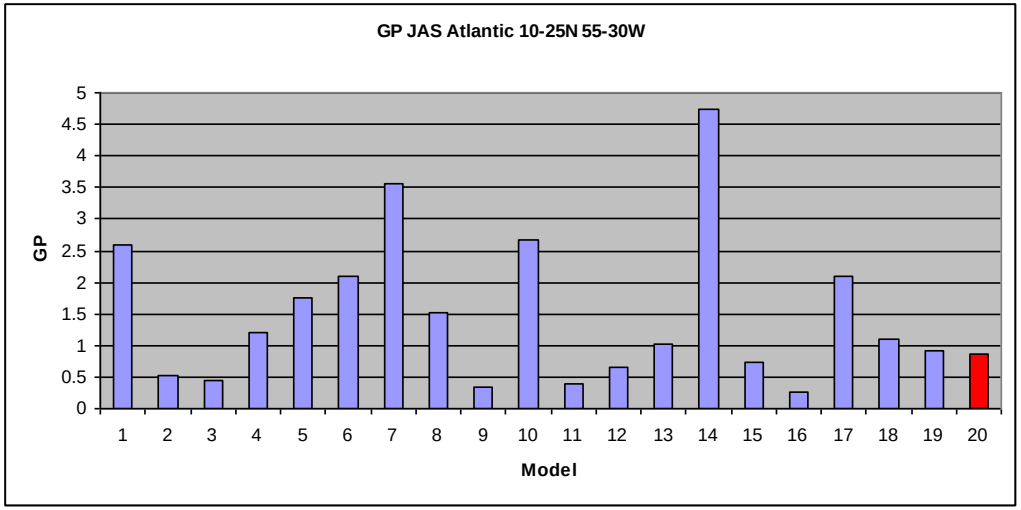


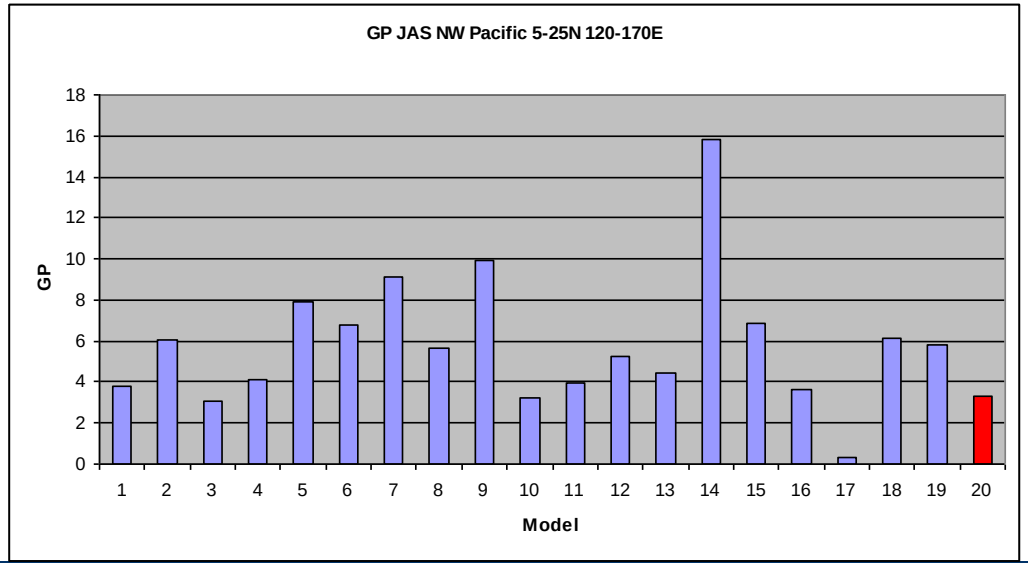






GP JAS – Atlantic and NW Pacific basins



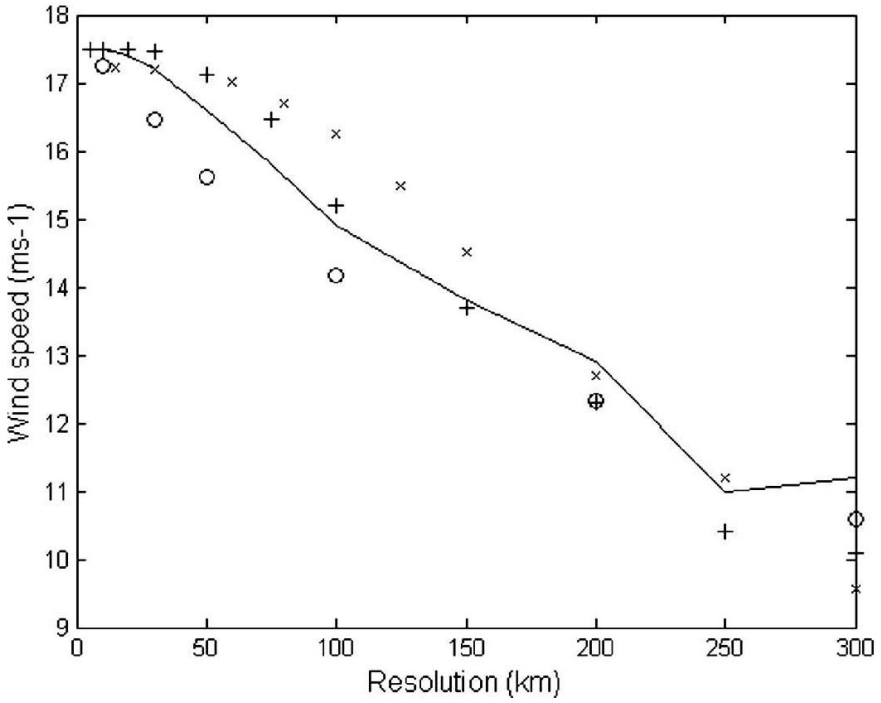


Metrics – Phase 2 (detection of lows)

- Consistent detection routines for all simulations:
  - Walsh et al. (2007) J. Climate
  - Camargo et al. (2002) Wea. Forecast.
  - Your detection and tracking routine but with detection thresholds adjusted for consistency with common metrics

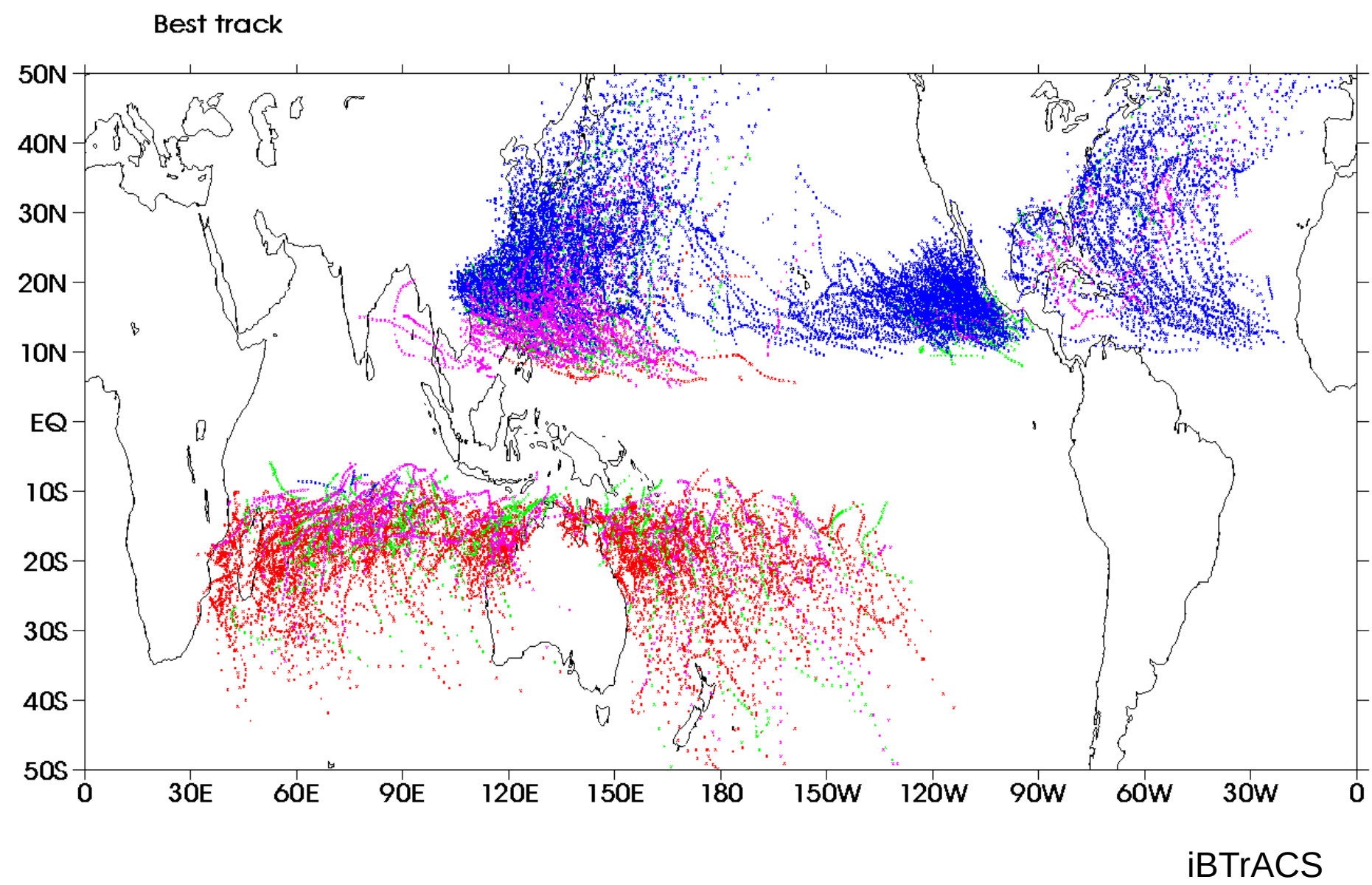
Detection routines – Walsh et al. (2007)

- Resolution-dependent detection method derived from H*WIND hurricane analyses and extended best track data
- Tests native ability of models to generate storms



Detection routines – Camargo et al. (2002)

- Basin-dependent detection routine
- Based on a threshold 850-hPa relative vorticity (e.g. 2σ)
- Accounts for model biases to give better pattern of formation

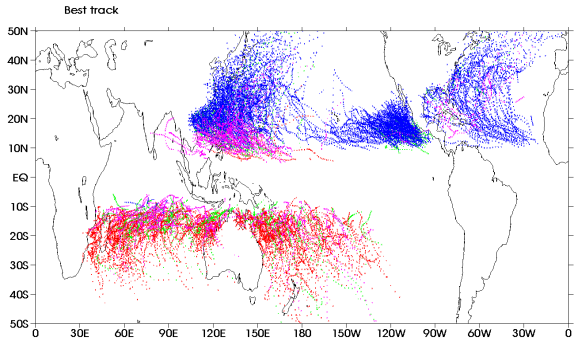


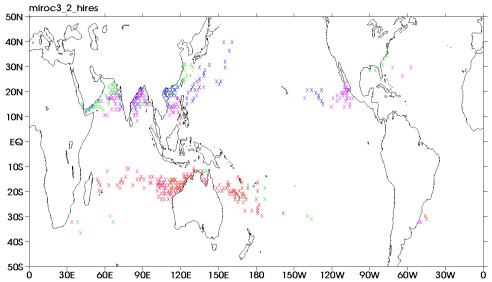
iBTrACS

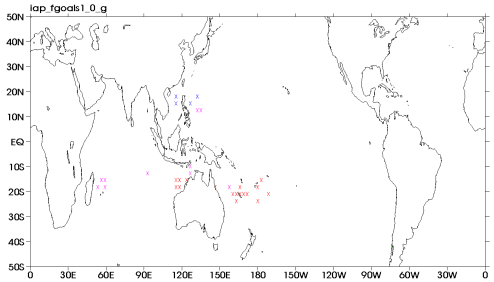
Red=JFM, Green=AMJ, Blue=JAS, Pink=OND

Data: CMIP3 model output

- Used for AR4 assessment
- Most models about T42 resolution, some T63
  - Models never designed for tropical cyclone simulation!
- Most data daily-average, some instantaneous
  - Affects TC detection


Best track


miroc3_2_hires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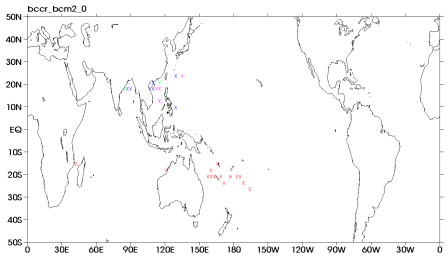
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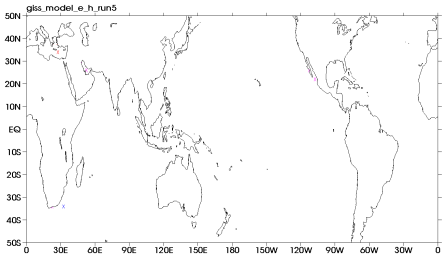
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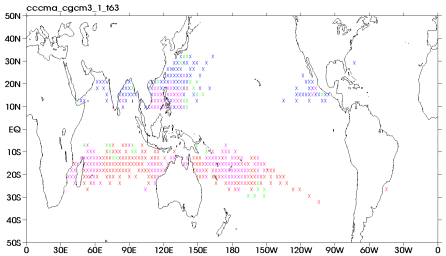
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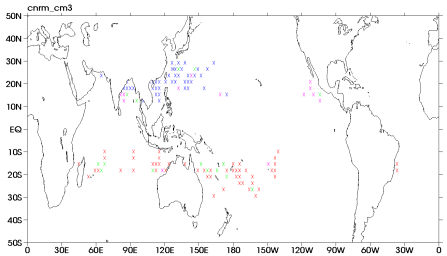
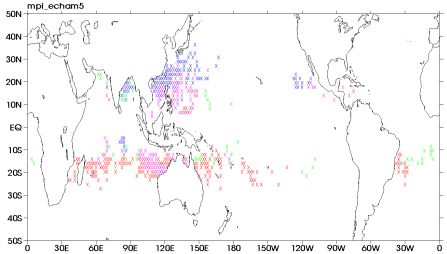
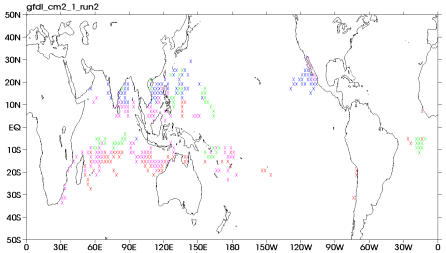

cnrm_cm3


mpi_echam5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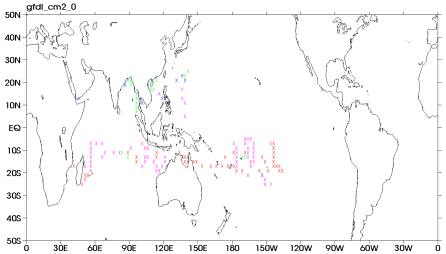
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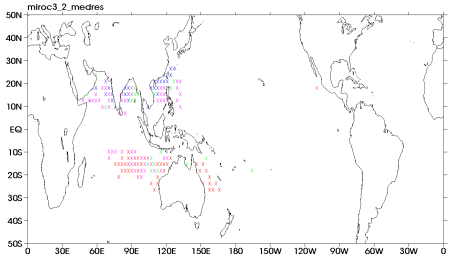
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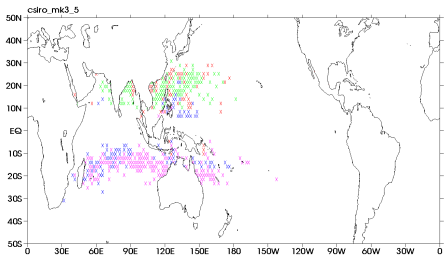
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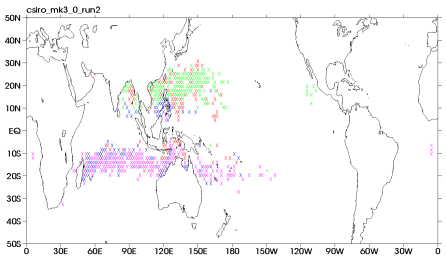
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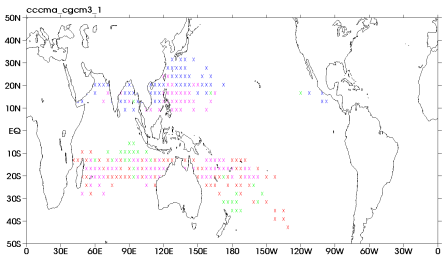
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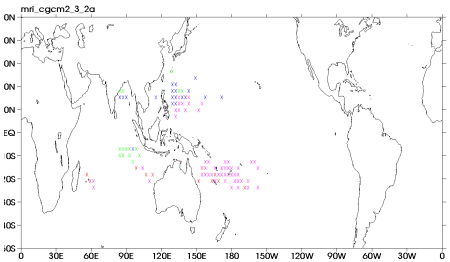
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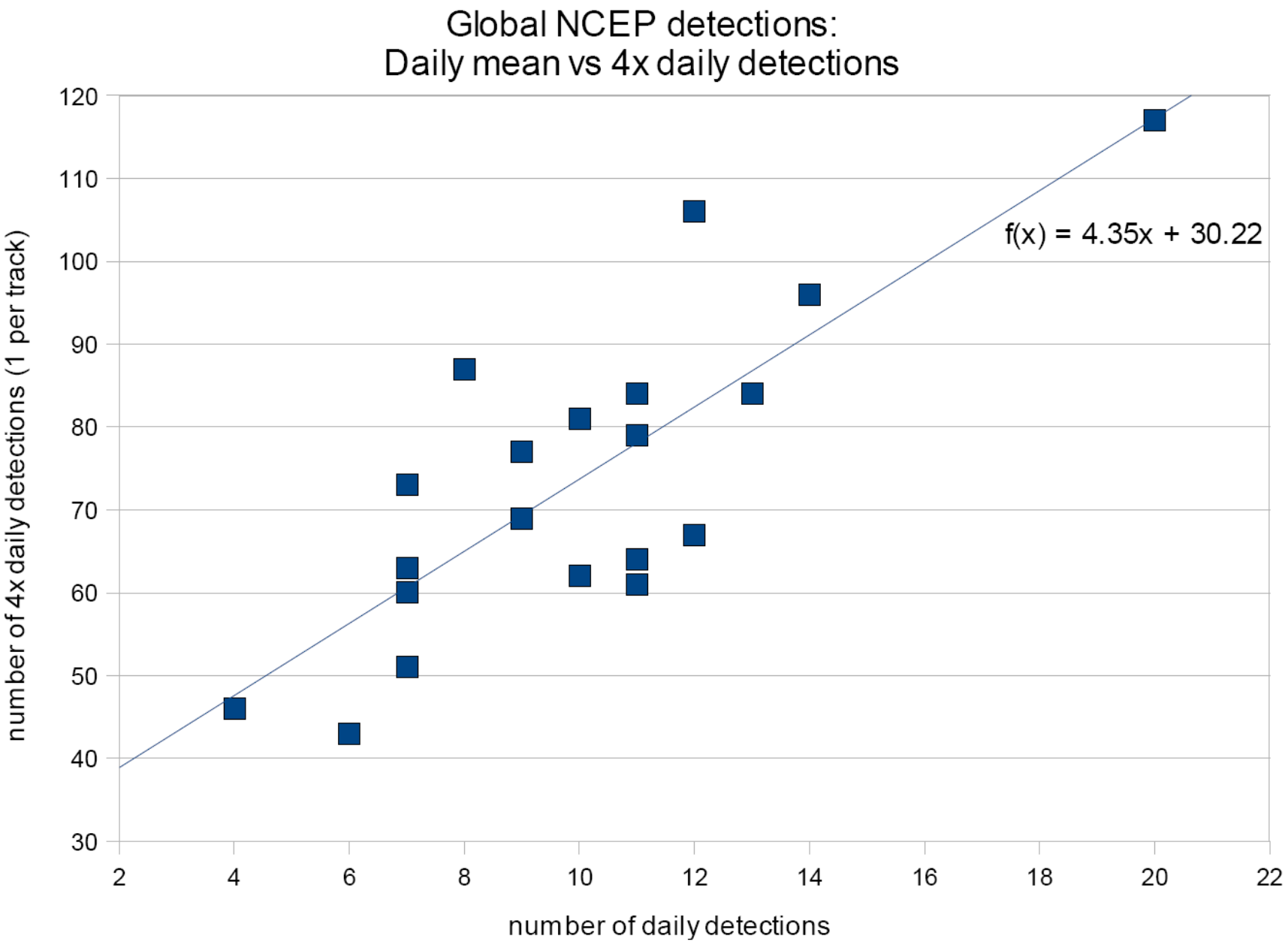
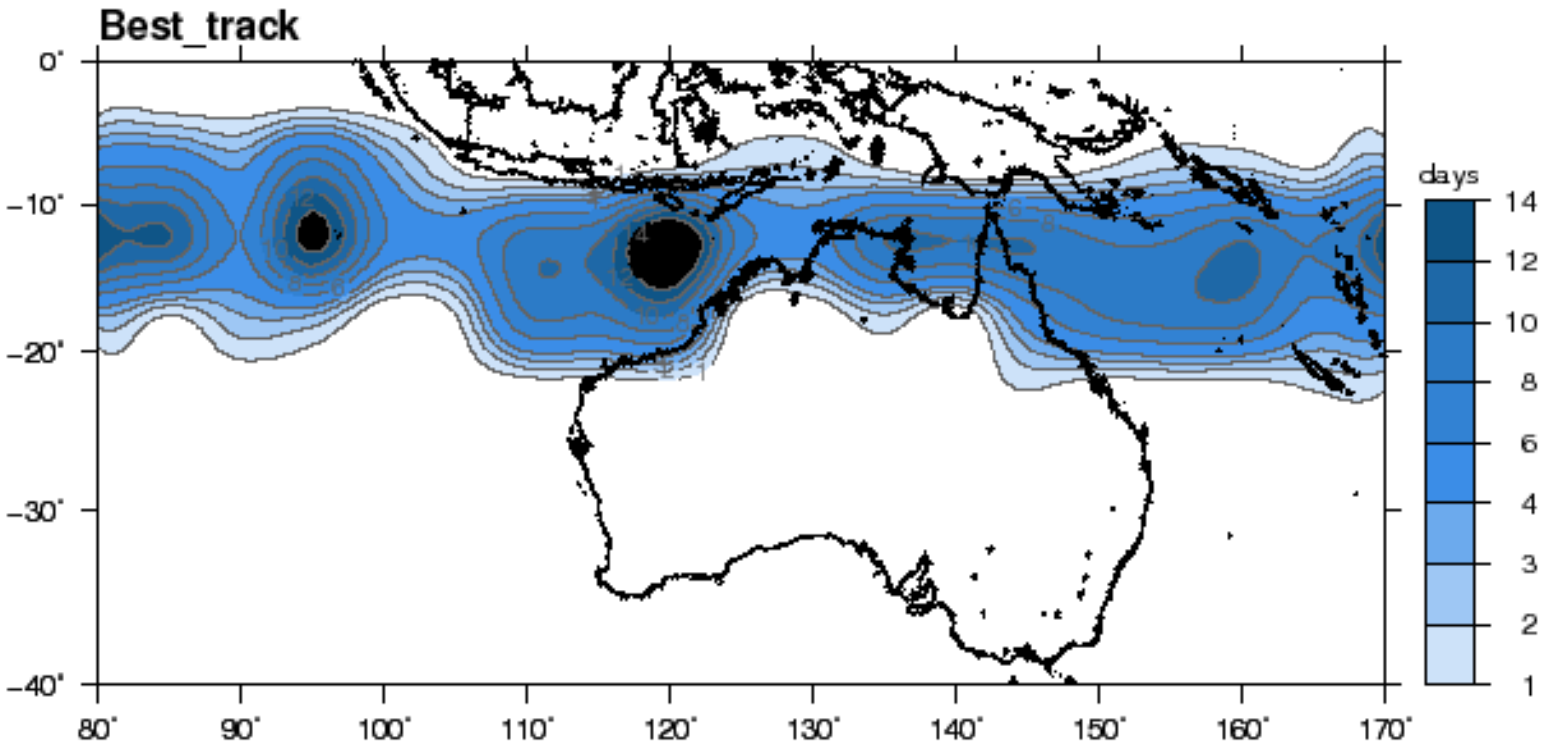
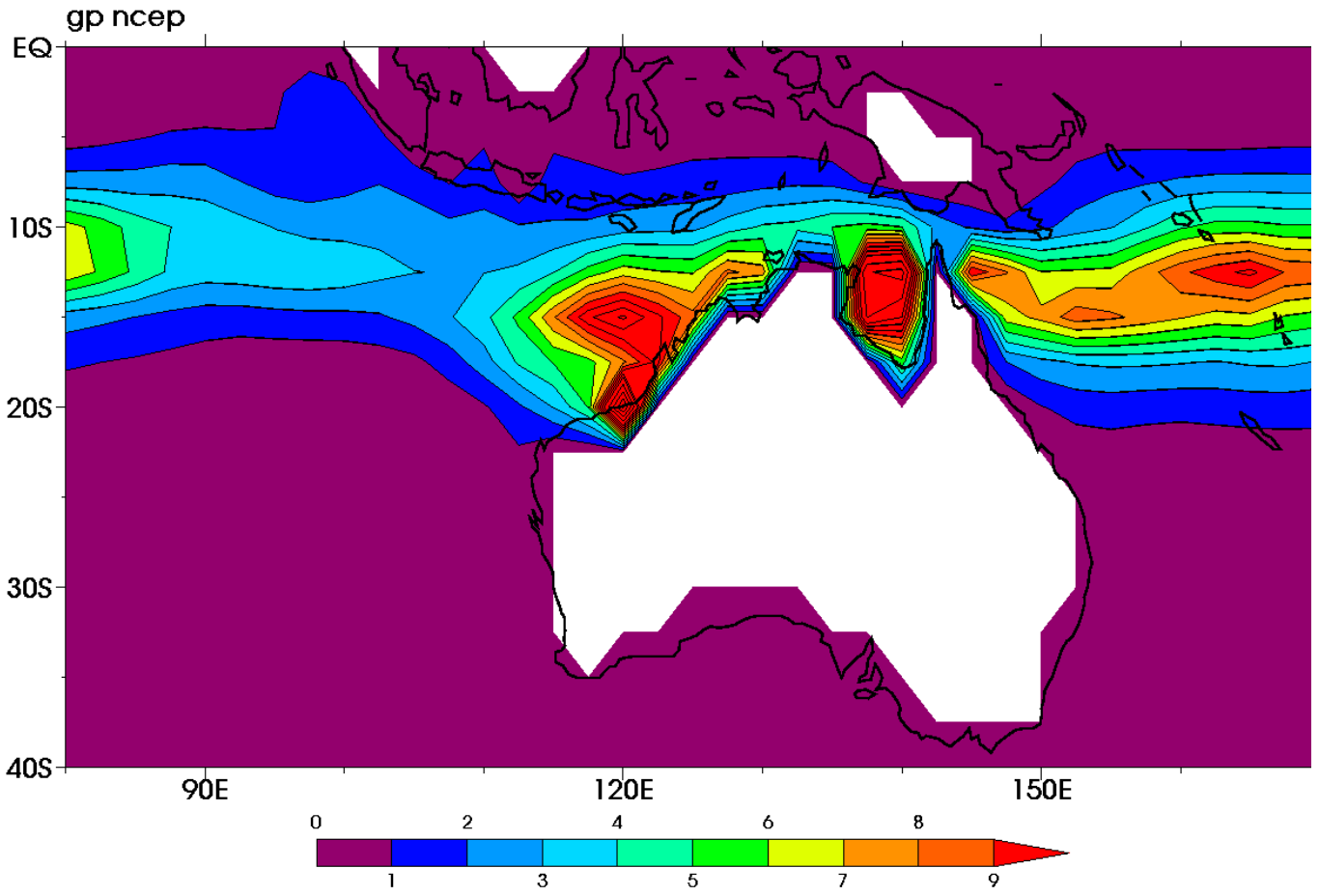

Global NCEP detections:
Daily mean vs 4x daily detections
f(x) = 4.35x + 30.22
number of 4x daily detections (1 per track)
number of daily detections
120
110
100
90
80
70
60
50
40
30
2
4
6
8
10
12
14
16
18
20
22

Best track data – formation (yearly 5x5 deg)

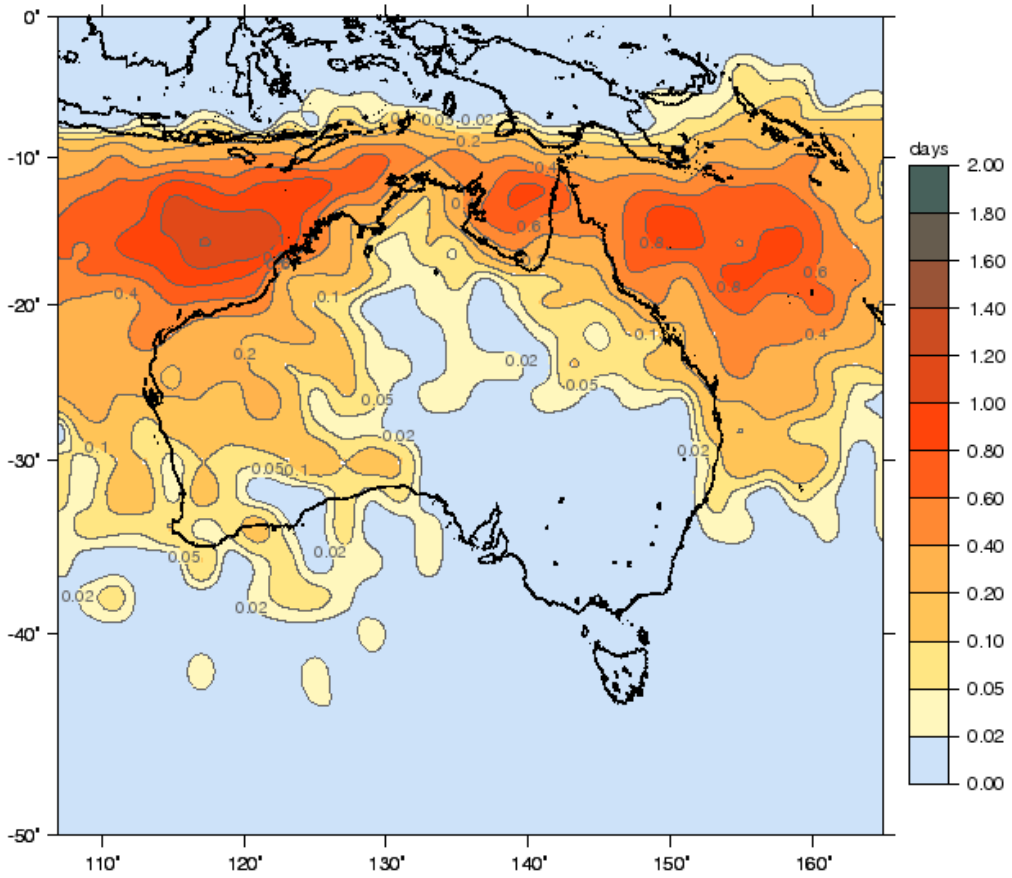


80% of formation in JFM

Emanuel and Nolan GP – JFM NCEP



Best track data Australian region – occurrence (JFM 2x2)

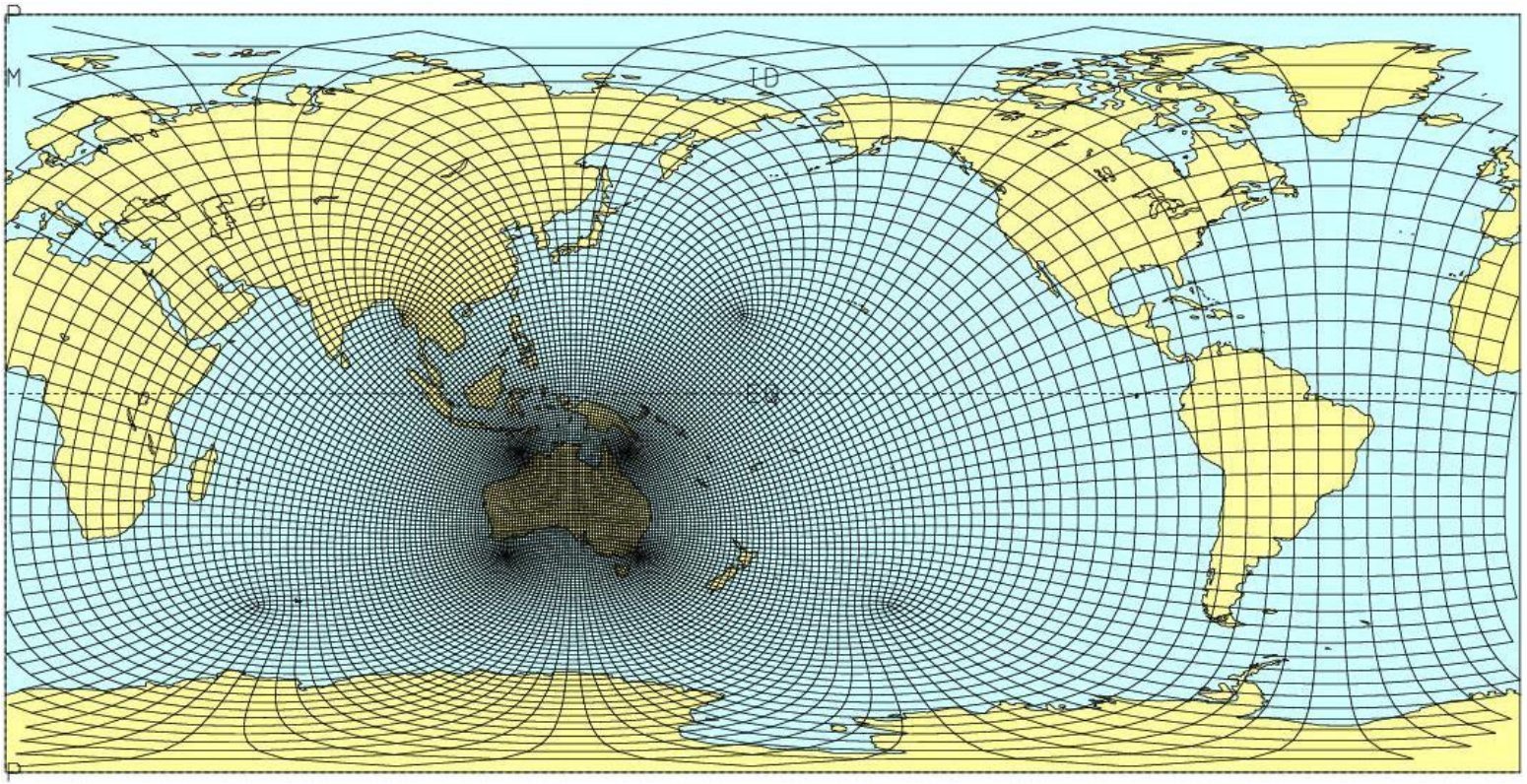


CSIRO

Comparison between low-res and high-res results

- CCAM
  - Developed by CSIRO
  - Variable-resolution climate model
    - Conformal-cubic grid
  - Semi-implicit, semi-Lagrangian
  - ~60 km resolution over area of interest (C48, Schmidt factor 0.3)
  - Nested within daily-average CMIP-3 model output
    - Spectral nudging in mid-troposphere where diurnal cycle is weak (technique developed by Marcus Thatcher, CSIRO)

CCAM – C48, Schmidt factor 0.3



McGregor 2006

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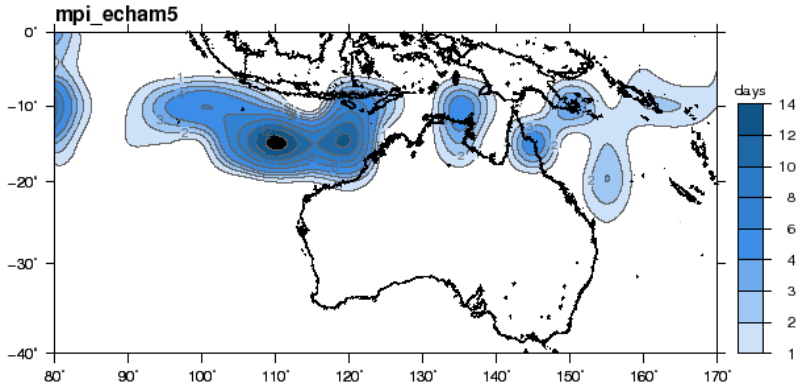
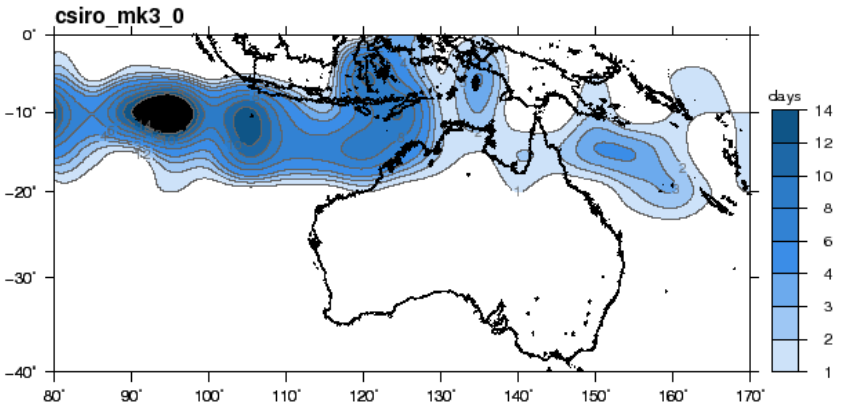
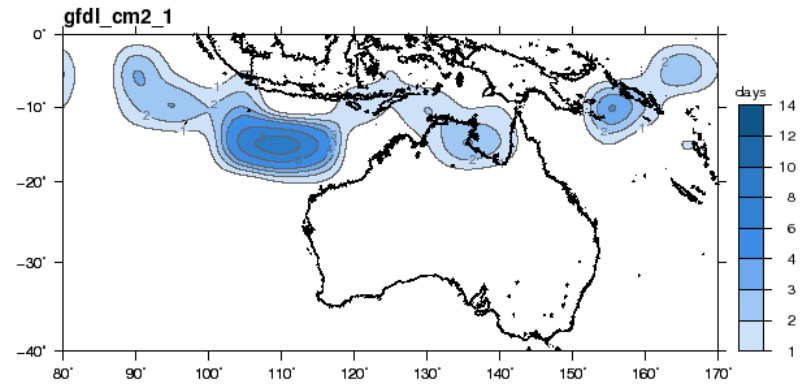
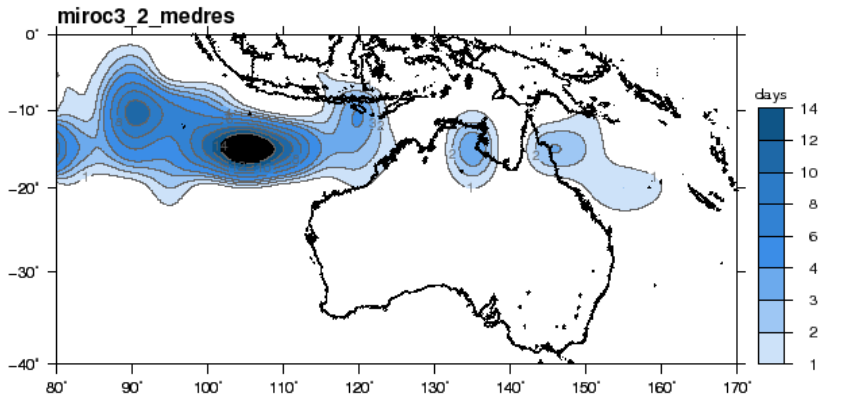
GCM genesis – numbers per 5x5 deg.

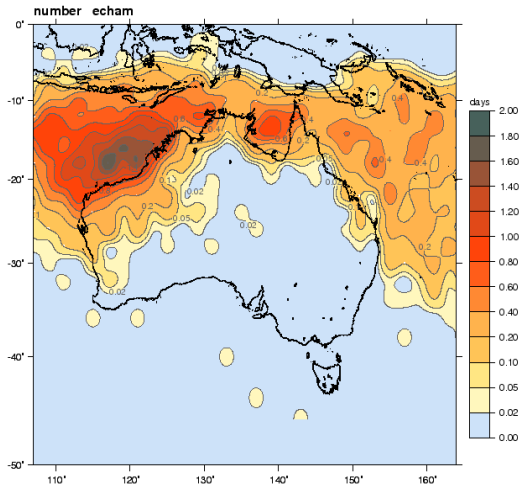


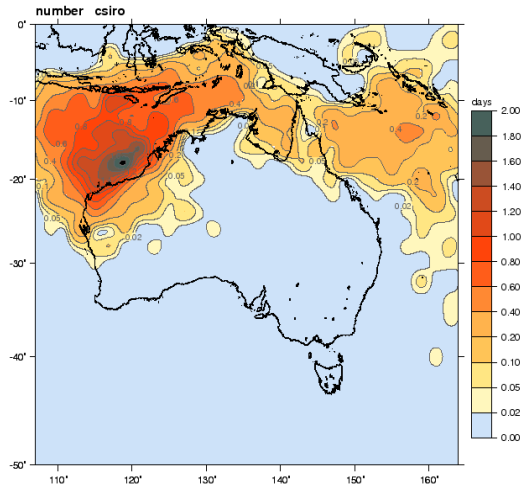


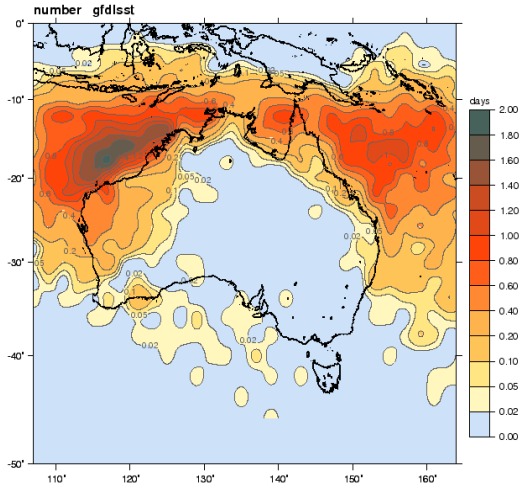


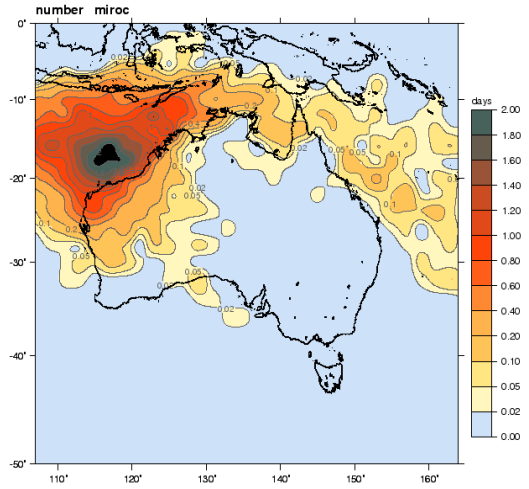


CCAM simulations – TC occurrence per 2x2 deg.









Marcus Thatcher,
Debbie Abbs, CSIRO

Summary

- Biases in TC patterns of formation at low resolution tend to persist when downscaled to higher resolution
  - Although we need to quantify this relationship better
- As a result, nested model can give very different TC formation if forced by different models

Future work

- Global high-resolution model TCMIP intercomparison
  - Now accepting data submissions, results
  - Suggestions welcome!
  - Aiming to meet IPCC AR5 deadline for papers in press (2012) which means analysis should be completed by 2011
- Model grouping by parameterization, resolution
- Literature review and evaluation